Intel(R) Threading Building Blocks

Getting Started Guide

Intel® Threading Building Blocks is a runtime-based parallel programming model for C++ code that uses threads. It consists of a template-based runtime library to help you harness the latent performance of multicore processors. Use Intel® Threading Building Blocks to write scalable applications that:

- specify tasks instead of threads
- emphasize data parallel programming
- take advantage of concurrent collections and parallel algorithms

This guide provides a complete example that uses Intel® Threading Building Blocks to write, compile, link, and run a parallel application. The example shows you how to explore a key feature of the library and to successfully build and link an application. After completing this guide, you should be ready to write and build your own code using Intel® Threading Building Blocks.

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Revision History

<table>
<thead>
<tr>
<th>Document Number</th>
<th>Revision Number</th>
<th>Description</th>
<th>Revision Date</th>
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<tbody>
<tr>
<td>314904-001</td>
<td>001</td>
<td>Applied new template.</td>
<td>August 2006</td>
</tr>
</tbody>
</table>
1 Note Default Directory Paths

Before you begin, make sure you have successfully installed Intel® Threading Building Blocks on your machine. Otherwise, install it according to the instructions in INSTALL.txt.

The default locations for the bin, doc, and examples directories used in this document are shown in the following table:

<table>
<thead>
<tr>
<th>Platform</th>
<th>Default Directories</th>
</tr>
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<tbody>
<tr>
<td>Linux∗</td>
<td>/opt/intel/tbb/1.1/[bin</td>
</tr>
<tr>
<td>Mac OS∗</td>
<td>/Library/Frameworks/Intel_TBB.framework/Versions/1.1/[bin</td>
</tr>
<tr>
<td>Windows’ with Intel® IA-32 processor</td>
<td>C:\Program Files\Intel\TBB\1.1[doc</td>
</tr>
<tr>
<td>Windows’ with Intel® 64 Instruction Set Architecture (ISA)</td>
<td>C:\Program Files (x86)\Intel\TBB\1.1[doc</td>
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</tbody>
</table>
2 Register Environment Variables (Linux* and Mac OS* only)

Before using Intel® Threading Building Blocks, you must register the environment variables that are used to locate necessary library and include files as follows:

1. Locate the configuration scripts for your operating system. The scripts are located in the bin directory.
2. Execute the appropriate scripts for your operating system. On Linux* and Mac OS* Systems, from the bin directory, source the tbbvars.[c]sh script. These scripts modify the paths held by the LD_LIBRARY_PATH, DYLD_LIBRARY_PATH (Mac OS), and CPATH variables, and affect only your current shell.
3 Develop an Application Using parallel_for

This section presents a basic example that uses the parallel_for template in a substring matching program. For each position in a string, the program displays the length and location of the largest matching substring elsewhere in the string.

Consider the string “babba” as an example. Starting at position 0, “ba” is the largest substring with a match elsewhere in the string (position 3).

You can refer to a complete version of this program in the Intel® Threading Building Blocks examples/GettingStarted folder. Or you can follow the step-by-step development of this application given here. In this section, new code that is added in each step is shown in blue. Code that is carried over from a previous step is shown in black. Lines are numbered in the order they appear in the final completed example.

To develop the example code:
1. Create a new empty application.
   - In the main function, initialize the task scheduler by instantiating a task_scheduler_init object (line 37).
     - Any thread that uses an Intel® Threading Building Blocks algorithm must have an initialized task_scheduler_init object. In this example, the default constructor for the task_scheduler_init object informs the task scheduler that the thread is participating in task execution, and the destructor informs the scheduler that the thread no longer needs the scheduler.
     - The definition for the task_scheduler_init class is included from the task_scheduler_init.h header file (line 04).
     - The using statement imports the namespace tbb, in which all of the library’s classes and functions are found (line 07).

2. Create the example string that is transformed by the program (lines 38 - 40) and the arrays for holding the lengths of the largest matched substrings and their locations (lines 41 - 42).
The example generates a Fibonacci string consisting of a series of ‘a’ and ‘b’ characters.

3. Add statements to output the lengths and locations of the largest substring matches for each position (lines 45 - 46).

```cpp
01: #include <iostream>
02: #include <string>
04: #include "tbb/task_scheduler_init.h"
07: using namespace tbb;
08: using namespace std;
09: static const size_t N = 23;
36: int main() {
37:    task_scheduler_init init;
38:    string str[N] = { string("a"), string("b") };;
39:    for (size_t i = 2; i < N; ++i) str[i] = str[i-1]+str[i-2];
40:    string &to_scan = str[N-1];
41:    size_t *max = new size_t[to_scan.size()];
42:    size_t *pos = new size_t[to_scan.size()];
43-44:    // will add code to populate max and pos here
45:    for (size_t i = 0; i < to_scan.size(); ++i)
46:        cout << " " << max[i] << "(" << pos[i] << ")" << endl;
47:    return 0;
48: }
```

4. Add a call to the parallel_for template function (lines 43 - 44).
The first parameter of the call is a blocked_range object that describes the iteration space.

`blocked_range` is a template class provided by the Intel® Threading Building Blocks library. The constructor takes three parameters:

- The lower bound of the range.
- The upper bound of the range.
- The `<grainsize>`. The parallel_for subdivides the range into sub-ranges that have approximately `<grainsize>` elements.

The second parameter to the `parallel_for` function is the function object to be applied to each subrange.

```cpp
01: #include <iostream>
02: #include <string>
04: #include "tbb/task_scheduler_init.h"
05: #include "tbb/parallel_for.h"
06: #include "tbb/blocked_range.h"
```
Develop an Application Using parallel_for

```
07: using namespace tbb;
08: using namespace std;
09: static const size_t N = 23;
10: class SubStringFinder { 
11:   const string str;
12:   size_t *max_array;
13:   size_t *pos_array;
14:   public:
15:     void operator() ( const blocked_range<size_t>& r ) const { 
16:       for ( size_t I = r.begin(); I != r.end(); ++I ) {
17:         ...
18:       }
19:     }
20:   }
21:
22: int main() {
23:   task_scheduler_init init;
24:   string str[N] = { string("a"), string("b") };  
25:   for (size_t i = 2; i < N; ++i) str[i] = str[i-1]+str[i-2];
26:   string &to_scan = str[N-1];
27:   size_t *max = new size_t[to_scan.size()];
28:   size_t *pos = new size_t[to_scan.size()];
29:   parallel_for(blocked_range<size_t>(0, to_scan.size(), 100),
30:     SubStringFinder( to_scan, max, pos ) );
31:   for (size_t i = 0; i < to_scan.size(); ++i)
32:     cout << " " << max[i] << "/" << pos[i] << endl;
33:   return 0;
34: }
```

5. Implement the body of the parallel_for loop (lines 10 – 35). At runtime, the template parallel_for automatically divides the range into subranges and invokes the SubStringFinder function object on each subrange.

6. Define the class SubStringFinder (line 10) to populate the max and pos array elements found within the given subrange. At line 16, the call r.begin() returns the start of the subrange and the r.end() method returns the end of the subrange.

```
01: #include <iostream>
02: #include <string>
03: #include <algorithm>
04: #include "tbb/task_scheduler_init.h"
05: #include "tbb/parallel_for.h"
06: #include "tbb/blocked_range.h"
07: using namespace tbb;
08: using namespace std;
09: static const size_t N = 23;
10: class SubStringFinder { 
11:   const string str;
12:   size_t *max_array;
13:   size_t *pos_array;
14:   public:
15:     void operator() ( const blocked_range<size_t>& r ) const { 
16:       for ( size_t I = r.begin(); I != r.end(); ++I ) {
17:         ...
18:       }
19:     }
20:   }
21:
22: int main() {
23:   task_scheduler_init init;
24:   string str[N] = { string("a"), string("b") };  
25:   for (size_t i = 2; i < N; ++i) str[i] = str[i-1]+str[i-2];
26:   string &to_scan = str[N-1];
27:   size_t *max = new size_t[to_scan.size()];
28:   size_t *pos = new size_t[to_scan.size()];
29:   parallel_for(blocked_range<size_t>(0, to_scan.size(), 100),
30:     SubStringFinder( to_scan, max, pos ) );
31:   for (size_t i = 0; i < to_scan.size(); ++i)
32:     cout << " " << max[i] << "/" << pos[i] << endl;
33:   return 0;
34: }
```
17:     size_t max_size = 0, max_pos = 0;
18:     for (size_t j = 0; j < str.size(); ++j)
19:         if (j != i) {
20:             size_t limit = str.size() - max(i, j);
21:             for (size_t k = 0; k < limit; ++k) {
22:                 if (str[i + k] != str[j + k]) break;
23:                 if (k > max_size) {
24:                     max_size = k;
25:                     max_pos = j;
26:                 }
27:             }
28:         }
29:     max_array[i] = max_size;
30:     pos_array[i] = max_pos;
31: }
32: }
33: SubStringFinder(string &s, size_t *m, size_t *p) :
34:     str(s), max_array(m), pos_array(p) { }
35: }
36-48: // The function main starting at line 36 goes here
4 **Build the Application**

Intel® Threading Building Blocks is compatible with the GCC* and Microsoft compilers. This section assumes that you are using the Intel® C++ Compiler. You can use the GCC or Microsoft C++ compilers interchangeably in the directions given below.

**Building Code from the Examples Directory**

If you did not type the example in [Develop an Application Using](#) parallel_for, build from the completed source code provided in the examples/GettingStarted folder.

**Linux* or Mac OS* Systems**

1. `cd` to the examples/GettingStarted/sub_string_finder directory.
2. Type “make” to build and run the example.

**Windows* Systems**

*NOTE:* This section uses Visual Studio* .NET* 2003 (vc7.1) but you can use Visual Studio 2005 by replacing `vc7.1` with `vc8`.

1. Invoke Visual Studio on the examples\GettingStarted\sub_string_finder\vc7.1\sub_string_finder.sln file using one of the following methods:
   — Browse to the directory containing sub_string_finder.sln and double-click the file.
   — Invoke Visual Studio from the Start menu, and then open the sub_string_finder.sln file via File ➔ Open ➔ Open Project.
2. Press <Ctrl-F5> to build and run the example.

**Building Manually Typed Code**

If you manually typed the code provided in [Develop an Application Using](#) parallel_for, build your application by invoking the appropriate compiler directly:

**Linux* or Mac OS* Systems**

Use the command line:

```bash
icc sub_string_finder.cpp -ltbb
```
Windows* Systems from the Command Line

From within the Intel® C++ Compiler build environment issue the following command:

```bash
icl /MD sub_string_finder.cpp tbb.lib
```
5 Run the Application

To run the application you built:

1. Run the application as you would normally. When run, the program outputs a long list of length and location pairs.

2. Optionally, to compare the performance of this example to a sequential version, you can build and run the extended version of the SubStringFinder example located in the Intel® Threading Buildings Blocks examples_GettingStarted folder as sub_string_finder_extended.cpp. This extended example calculates and displays the speedup obtained by using Intel® Threading Building Blocks to parallelize the algorithm compared to performing the same work sequentially.
Next Steps

To get the most out of the Intel® Threading Building Blocks library, explore the following additional resources.

1. **Tutorial** is a document that walks you through the major classes, algorithms and concepts used by Intel® Threading Building Blocks. This document is available in the *doc* directory as *Tutorial.pdf*.

2. **Reference** is a complete, detailed reference manual for all the functions and interfaces provided by Intel® Threading Building Blocks. It is available in the *doc* directory as *Reference.pdf*.

3. **Examples** includes a collection of example programs that demonstrate the various features of Intel® Threading Building Blocks. These programs are located within the *examples* directory. A good place to start is with the extended version of the *SubStringFinder* example presented in this *Getting Started Guide*. This extended example is found in the *examples/GettingStarted/sub_string_finder* subdirectory as *sub_string_finder_extended.cpp*. When run, it calculates and displays the speedup obtained by using Intel® Threading Building Blocks to parallelize the algorithm compared to performing the same work sequentially.

4. **Doxygen** includes documentation that was automatically generated from the comments in the Intel® Threading Building Blocks include files. The *Doxygen* subdirectory is found within the *doc* directory. The files in the *Doxygen* directory are in HTML format and are viewable with any browser that supports HTML.